ATTACHMENT 11
(per Addendum No. 9)

BATTERY ELECTRIC BUS DRIVING SIMULATION SYSTEM

FOR

PROCUREMENT OF 40 FT LOW-FLOOR BATTERY ELECTRIC BUSES

SPECIFICATION NO. VE21-054

Massachusetts Bay Transportation Authority
Vehicle Engineering
Boston, Massachusetts

TECHNICAL SPECIFICATION
BATTERY ELECTRIC BUS DRIVING SIMULATION SYSTEM (BDSS)

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TECHNICAL SPECIFICATION

1. GENERAL DESIGN REQUIREMENTS

1.1. System Overview

The Massachusetts Bay Transportation Authority's (MBTA) Bus Driving Simulation System (BDSS) shall be a fully interactive operator training simulator using street views (example: Google Maps) overlaid with existing Authority bus route operating profiles to simulate the bus driving experience representative of the MBTA's service environment and with an emphasis on safe and efficient operation of battery electric buses (BEB). The BDSS shall exactly mimic the RFP 1F-22 'as delivered and Authority accepted' base order battery electric bus.

The base BDSS shall include one (1) complete, fully interactive student training stations and one (1) supervisor station to oversee and control the training process.

The contractor shall provide a BDSS that meets all the MBTA's training objectives, such as defensive driving, good driving habits, initial qualification screening, reactionary skills evaluation, recertification, efficient operation of a battery electric bus, etc. The BDSS shall be used by MBTA's training staff to reinforce hands-on vehicle operation by providing realistic skill training in a simulation of a battery electric bus in the Authority's operating environment, and operating virtually on Authority routes. The simulated environment shall provide the student interaction with virtual traffic and pedestrians in realistic training scenarios. The instructor shall be able to select various "Driving Worlds" and various road surfaces, weather conditions, traffic conditions and vehicle faults/failures to give the student specific learning experiences. The BDSS shall operate on 120VAC / 60Hz single phase electrical service. The Contractor shall identify in their proposal the recommended space (provided on a dimensioned drawing) required within a facility to properly house the base BDSS.

1.2. Operational Capabilities

The BDSS shall present training opportunities with respect to basic skill development, situational awareness decision-making skills and judgment, vehicle maneuvering, electric bus range optimization, and skills assessment for operator trainees in the safe operation of the MBTA's new BEB fleet.

The driving simulation system shall be an authentic replication of the battery electric bus operator's compartment configuration as approved during the Technical Specification VE21-054 design review process. The operator's training module shall exactly mimic the battery bus being procured from the leading edge of front wheel well tubs/standee line forward. Customization of the operator's cab shall be discussed during the Initial Design Review Meeting. The operator station shall fully simulate bus operations in a virtual environment. The associated software shall create a realistic simulation using audio/visual stimulation, as well as seat vibration and resistance through the steering wheel and pedals.

The simulated driving environment shall include varied driving surfaces such as pavement, grass, gravel, and dirt/sand. Traction and sound variations shall reflect both dry and wet conditions. Different weather conditions shall be selectable by the instructor, including clear, variable fog, rain, black ice, and snow. Different light conditions shall also be selectable by the instructor for time-of-day training experiences including; day, night, or dawn/dusk, and solar glare. The simulator shall also

accurately portray Authority bus routes and bus stops for all runs/blocks originating at the North Cambridge, Quincy, and Arborway facilities.

1.3. Service Proven Requirement

The BDSS shall be based on proven bus simulator technology already in-use for training in other transit agencies' installations. To the greatest extent possible the BDSS shall utilize Commercial off-the- Shelf (COTS) computer hardware and software, and shall be upgradeable and expandable. The Contractor shall demonstrate their Service Proven qualification by submitting with their bid a list of at least 5 similar BDSS design installations delivered by the Contractor within the past 3 years. The Contractor shall also provide with their proposal, a contact person (references) at the other transit agencies where their bus simulators are currently in use.

1.4. Delivery Schedule

A fully tested and operational BDSS system shall be delivered to the Authority with acceptance no later than thirty day before delivery of the first RFP 1F-22 base order serial production bus.

The Contractor shall provide with their Technical Proposal, a schedule for delivery of the BDSS, including Design Review meetings, in-plant testing and acceptance, de-bugging, and BDSS delivery/installation.

2. DEFINITIONS, ACRONYMS AND ABBREVIATIONS

Approved or Approved Type: Design, type of material, procedure, or method given written acceptance by the Authority.

Authority (or MBTA): The Massachusetts Bay Transportation Authority is the regional transportation provider in the Boston metropolitan area created by Chapter 563, Section 18 of the Acts of 1964 of the Commonwealth of Massachusetts, the Party of the First Part to the Contract.

Bus Driving Simulation System (BDSS): A complete functioning training system including at a minimum one instructor workstation and one student driving station, conforming to these Technical Specifications.

Commercial Operator's License (CDL): A CDL is required to operate any vehicle with a GVWR of 26,001 pound or more. It is a federally mandated program which is regulated by the Federal Motor Carrier Safety Administration.

Contract Deliverable Requirement (CDR): CDRs are identified in the Technical Specification. They are specifically required submittals as defined in these contract documents.

Contractor: The person or persons, firm, partnership, corporation, or combination thereof which has entered into a procurement contract with the Authority to supply the BDSS. The prime contractor is solely responsible to the Authority for the quality and proper functioning of the BDSS and all components.

Contractor's Drawings: Items such as general arrangement drawings, detail drawings, graphs, diagrams, and sketches that are prepared by the Contractor to detail its work.

Equal: Whenever the words "equal" or "approved equal" are used in connection with make or quality of material or equipment, the proposed alternative shall be functionally compatible with and of equal or better quality than the item it is proposed to replace. The Technical Project Manager's decision as to whether any material or equipment proposed is equal to that specified shall be binding and final on both the Contractor and the Authority.

Inspector: The person or firm designated by the Authority as its quality assurance representative. A representative(s) of the Authority assigned to inspect functionality, materials, and workmanship in accordance with the technical specifications.

Reliability: The probability of performing a specified function without failure and within design parameters for the distance, under actual operating conditions.

Standards: Standards referenced in these Technical Specifications are the latest revisions unless otherwise stated.

Subcontractor: An individual, firm, partnership, corporation, or joint venture to whom the Contractor sublets any part, subsystem, component, or hardware for the Contract.

Supplier (or Subsupplier): Person(s), firm, partnership, corporation, or combination thereof who builds, produces, services, or supplies materials, equipment, or apparatus for installation on the BDSS. Supplier-furnished materials or services shall comply with all contract requirements.

Technical Project Manager: The person designated by the Authority to be its liaison with the Contractor on all technical matters pertaining to the work. The Technical Project Manager is empowered to act on behalf of the Authority in such matters as acceptance of Contractor's drawings, test procedures, First Article approvals, and BDSS acceptance. The Technical Project Manager is responsible for technical issues on behalf of the Authority, and shall be designated as such on official MBTA letterhead.

Time, Down: The lapsed time during which equipment is not capable of doing useful work because of maladjustment, malfunction, or maintenance-in-progress.

3. DESIGN REVIEW AND APPROVAL PROCESS

The Driving Simulation System Design Review and Approval Process shall be performed as part of Technical Specification VE21-054, CDR 45, and shall include a two-tier Design Review, which consists of an Initial Design Review and Follow-Up Design Review(s) as needed. Exhibit 1-1 provides a summary of specified requirements that are required to be approved by the Authority during this process. Exhibit 1-1 is provided for the convenience of the Contractor and remains subject to modification by the Authority during contract execution. The Contractor shall prepare and submit a Design Review Plan and Schedule for the Authority's review and approval.

EXHIBIT 1-1
Authority Approvals

Bus Operator's Station
Dash Layout
Interior Colors
Operator's Seat
Mirror layouts – actual and virtual
Training Plan
Student Reports and Database
Route Profiles
Graphics and Display Image Quality
Steering Wheel / Column Assembly
Pedal Assembly (brake and accelerator)
Instructor's Console and Controls
All Manuals and Plans

3.1. Initial Design Review Meeting

The objective of the Initial Design Review Meeting shall be for the Contractor to present all appropriate preliminary design details of the proposed BDSS for the Authority's review and approval. This meeting shall occur in conjunction with the Technical Specification Final Design Review meeting. At the meeting, the Contractor shall present, at a minimum the following deliverables for Authority review:

a) Preliminary Bus Operator station (training module) layout
b) Preliminary Instructor workstation layout and controls
c) Interior colors
d) Operators seat
e) Graphics and display image quality
f) Preliminary Test Program Plan
g) Training Program Plan
h) Manual outlines
i) Schedule including CDR submittals
j) Design and Manufacturing Plan

The Initial Design Review Meeting shall be held at the Contractor's manufacturing facility. In addition to the above items, the Contractor should be prepared to present any and all items critical to design, delivery, testing, acceptance, and overall contractual performance. The Contractor shall provide a demonstration of their simulator designs and identify any features that remain undeveloped or features that must be customized in order to meet the Authority's specification requirements.

3.2. Final Design Review Meeting(s)

The objective of the Final Design Review Meetings shall be for the Contractor to gain Authority approval for all those items not approved during the Initial Design Review and freeze the design of the BDSS system. This meeting shall be held one week after Authority acceptance of the first base order pilot bus meetings and may be held at the Contractor's manufacturing location, Authority locations in the Boston MA. area, or by remote/teleconference, with locations chosen at the discretion

of the Authority. During Final Design Review meeting, any open issues identified, shall be discussed along with any new submittals. The review and discussions shall include, but not limited to the following:

a) Confirmation Operator's training module exactly mimics the base order pilot bus
b) Operator's layout
c) Outlines for simulation training exercises
d) Student reports and databases
e) Design of MBTA specific software
f) Authority route profiles
g) Final version of all manuals

The Contractor may be required to attend additional meetings, scheduled at the Authority's discretion, to address open issues or concerns. These additional meetings may be at either the Contractor's facility, MBTA offices in Boston or by remote teleconference.

3.3. In-Plant Pre-Shipment Testing & Acceptance

Prior to shipping to the MBTA the BDSS shall by fully tested and demonstrated as functional at the Contractor's facility. MBTA representatives shall be present during the testing and shall participate as students and/or instructors in the verification of the simulator scenarios. All defects and discrepancies noted shall be addressed to the Authority's satisfaction prior to shipment or as mutually agreed. (refer to Section 11, 12, and 13 for testing requirements)

3.4. Delivery and Final Installation

The Contractor bears full responsibility for all related costs for the transport, delivery, installation, and testing of the BDSS and any related equipment, to the Authority's F.O.B. destination facility in the Boston area. After installation, the Contractor shall fully test and demonstrate the BDSS as fully functional prior to formal Acceptance.

4. TRAINING, DOCUMENTATION AND PRODUCT SUPPORT

The Contractor shall provide the appropriate documentation for complete comprehension and operation of the BDSS. These documents shall include, but are not limited to, component adjustment and settings, student and instructor operating manuals, systems maintenance manuals, and systems programming manuals.

The Contractor shall provide in-person training at the Authority's BDSS training location. Training for instructors, operators and maintenance personnel shall conform to the Authority's training and maintenance objectives. Training shall be conducted on-site for no less than twelve MBTA instructors - utilizing the train the trainer approach. A syllabus identifying all training shall be submitted during the Initial Design Review meeting. The syllabus must specify that each instructor shall receive no less than twenty-four hours of training. The Contractor's trainer shall train no more than three (3) instructors at a time.

The first training session for instructors shall commence no later than five calendar days following Authority acceptance of the BDSS. The training program shall provide instructors with

familiarization and functionality of the BDSS as well as advanced training techniques that may be used by the instructors to meet all of the MBTA's training objectives. Actual dates and schedule to be approved by MBTA.

Training shall commence no later than five calendar days following Authority acceptance of the BDSS. The Contractor shall include and submit the following requirements as part of their CDR submittals during Design Review meetings:

a) Twelve (12) complete sets of instructor, operator and maintenance manuals and five (5) electronic copies on individual secure USB flash drives in PDF format
b) Complete training program on all operational aspects and maintenance requirements of the delivered BDSS on MBTA property. All training shall be performed by the Contractor at the Authority's BDSS location
c) Train Authority instructors to reinforce existing Authority bus training and to promote BEB energy consumption best practices
d) Train Authority instructors how to re-construct accidents, conduct post-accident training, and how to tailor training scenarios to MBTA specific objectives
e) Instructor guides and lesson plans detailing the recommended training exercises and instructions for advanced exercises. The advanced exercises shall teach instructor's how to create scenarios suitable for the MBTA's advanced training objectives
f) Best practices from peer agencies for integrating simulator-based training into the MBTA's existing transit bus training program.
g) A recommended spares list shall be provided
h) An additional eighty (80) hours of refresher training for BDSS instructors shall be provided within the first 12 months after delivery of the BDSS. Dates and schedule to be approved by the Authority. All refresher training shall be performed by the Contractor at the Authority's BDSS location

5. CONTRACT DELIVERABLES REQUIREMENTS (CDR) LIST

The Contractor shall provide matrix to reference and track the specified contract deliverables. The Contractor bears the responsibility for submitting a complete and comprehensive contract deliverables schedule in accordance with Section 3 for the MBTA review and approval. The Contractor's proposed schedule for CDR tracking shall include the following information:

a) CDR #
b) Title and Description
c) Contract Specification Reference
d) Reason for Submittal (information or approval)
e) Required Submittal Date
f) Actual Submittal Date
g) Current Status and Any Other Pertinent Information.

6. BUS SIMULATOR CONFIGURATION

The simulator shall completely mimic the battery electric bus as procured by RFP 1F-22.

6.1. Enclosure

The student driving station shall be a standalone enclosure that replicates the MBTA's standard operator's environment of the MBTA's new low floor battery electric bus. The enclosure shall be of sturdy metal, or approved durable construction and shall include the typical front dash assembly, operator's side panel, operator's seat riser, flooring, ceiling/header, driver's protection system, front entrance doors, stanchions/grabrails, internal and exterior mirrors, Luminator/Twin-vision sign, fire detection system indicator panel, and mobility device ramp. The enclosure shall replicate the operator's cabin and include a non-functioning mock-up of the Authority's Cubic fare validator. The exterior of the enclosure shall be painted in the Authority's colors with appropriate decals, logos, and signage. The Authority shall provide all decals, logos and signage (unique to the Authority's buses) as identified and requested by the Contractor at the Initial Design Review meeting. The final layout of the enclosure is subject to MBTA approval during the Initial Design Review.

6.2. Optical/Visual System

The operators viewing area shall be surrounded by high resolution UHD (Ultra HD) video screens providing a continuous 180 degree field of view. Visual System screens shall operate at 120 Hz or greater refresh rate, 1 ms or less response time, and 120 fps frame rate. The transition from one screen to the next shall not distort or interrupt the simulation. To the greatest extent possible screen edges and transitions shall be hidden in the natural blind spots of the Authority's new BEB.

The instructor's console will have an identical viewing area as the bus operator/trainee.

6.3. Operator' Seat

The operators seat shall be the Recaro Ergo Metro high back seat as installed in the BEB. The seat shall be fully adjustable using the same controls found on the standard MBTA seat. The seat shall have a retractable two-point seat belt. Function of the "unseat alarm" (Technical Specification VE21-054, Section 40.6) shall be the same as the BEB and will provide status notification to the instructor.

6.4. Mirrors

The Authority has a standard training procedure for adjustment of all mirrors. The use of the bus mirrors is a critical component the MBTA's driver training program.

6.4.1. Exterior Mirrors

The Contractor shall replicate the exact installation location of the exterior mirrors on the Student driving cabin. The exterior mirrors shall be the same as installed on the BEB and shall have the same functionality and adjustability as the actual BEB. It shall be possible to easily dismount the mirrors

from the driving cabin with basic hand tools. Storage shall be incorporated for the mirrors within the Student Driving Station.

6.4.2. Virtual Mirrors.

The simulation shall also provide virtual mirrors imbedded in the simulation screens which shall realistically replicate the views seen in both the flat mirror and the convex mirror. Exterior mirrors must accurately mimic the location and function of BEB mirrors including integrated turn signals, integrated heaters , positioning, and electronically adjustable flat and convex mirror glass. The instructor shall have the ability to turn the convex mirrors on/off. Note: the use of virtual mirrors or actual exterior mirrors shall be selectable by the Instructor.

During the mirror setup procedure in the virtual world it is required that chock blocks appear at the street side and curb side rear wheel locations for assistance with mirror alignment. Once the operator has completed the mirror setup the instructor shall have the capability of making the chock blocks disappear.

6.4.3. Interior Bus Mirror.

The Contractor shall replicate the exact location and function of the front interior mirrors.

a) Aisle mirror – convex mirror that provides a wide view of the entrance door and passenger area
b) Upper right mirror – used to view the rear mirror
c) Overhead convex mirror – provides a view of the entrance door and the adjacent curb

Each mirror shall be fully adjustable and shall permit the student to view forward facing/rear mounted video screens. Location of the forward facing/rear mounted screens

6.5. Instructor Viewing Camera

The Contractor shall install closed circuit cameras in the student driving station which shall provide the instructor an unobstructed view of the student operating the simulated bus. Cameras shall be positioned so that the instructor can observe the students eye movements, operation of all hand operated bus controls (including steering wheel, parking brake valve, and all front and side dash controls), and foot controls (including accelerator and brake pedals and directional switches).

The instructor’s console shall have a separate viewing screen that permits the instructor to simultaneous view of each camera image, or an individual camera feed.

All closed circuit camera images shall be recorded and shall be a synced component of the stored student records.

6.6. Operator’s Cab

The operator’s cab inside the enclosure shall contain all of the same controls and instrumentation arranged in the same spatial orientation to replicate the RFP 1F-22 base order battery electric bus as

delivered and accepted by the Authority. To the greatest extent practical, the Contractor shall use *actual* components, gauges, controls, and instruments found on the BEB. All gauges and indicators shall function in an equivalent manner as the BEB or as approved at the design review meetings.

6.7. Operator's Dash Panel

The complete layout and configuration of the operator's front and side dash panels shall be approved by the Authority during the design reviews. The location, type, and function of all switches, controls, and indicators shall be the same as the BEB.

6.8. Operator's Side Panel

The complete layout and configuration of the operator's front and side dash panels shall be approved by the Authority during the design reviews. The location, type, and function of all switches, controls, and indicators shall be the same as the BEB.

All door control, air dump valves, brake valves, switches and instrument panel lighting shall be the same as the BEB.

6.9. Operator's Controls

The complete layout and configuration of the operator's controls shall be approved by the Authority during the design reviews. The location and function of all switches, controls, and indicators shall be the same as the BEB. All operator control components shall be the same as found on the BEB.

a) Steering wheel – with tilt, telescope adjustment
b) Accelerator pedal
c) Brake pedal
d) Propulsion mode control
e) Turn signal (foot operated)
f) Operator's area light
g) Horn button in steering wheel hub
h) Headlight dimmer (foot operated, waterproof)
i) Emergency alarm (foot operated, silent, momentary contact)
j) Fire detection system monitor

6.10. Drive Mode Selection

The drive mode selector shall have the same functionality as the actual BEB selector.

6.11. Steering Column Assembly

The steering column assembly shall be equipped be the same as installed in the BEB. Installation of the steering column shall be the same angle, height, and position, as the BEB. A horn button shall be incorporated into the center of the steering wheel. The following additional features should be provided:

a) The steering wheel shall replicate the lock-to-lock turning rotation of the BEB.
b) The steering wheel shall provide realistic force feedback to simulate vehicle performance, turning radius, road feel, directional maneuvers, wheel return, and tire contact (e.g. contact with curb, railway tracks, etc.). This feature shall be Authority adjustable.

6.12. Pedal Assembly

The brake and accelerator pedals shall be mounted on the floor of the operator's compartment to the right of the steering column. The pedals shall be positioned, configured, and function the same as those found on the BEB. The following additional features shall be provided:

a) Application of the brake and accelerator pedals shall simulate typical BEB brake and propulsion system control response in accordance with student's actions, the condition of the vehicle, and the nature of the training exercise.
b) Application of the brake and accelerator pedals shall cause the appropriate gauges and indicators to activate on the front dash assembly.
c) Regenerative braking must operate the same as the BEB and provide the same feedback to the operator/trainee
d) The instructor shall have the ability to turn off regenerative braking

6.13. Directional Signals and Headlight Dimmer Switch

The directional signal switches shall be foot activated and be positioned and function the same as those found on the BEB. Activation of the directional switches and headlight dimmer switch shall provide the same dash panel indication as the BEB.

6.14. Driver's Protection System

A fully functioning Arow Global AROWGUARD Slide Stow Driver Protection System shall be installed per TS VE21-054 Section 64.2

6.15. Bicycle Rack

The simulation will include a bicycle rack per the requirements of Technical Specification VE21-054, Section 78, which can be programmed by the instructor to be folded up or secure one or two bicycles. The simulation shall project bicycle rack image onto the display and accurately portray the effects on the bus operator's field of view. The instructor shall have the ability to turn this function on and off.

7. INSTRUCTOR'S CONSOLE

The Instructor's Console shall have all of the controls and programming to initiate the BDSS, set up the simulation exercises, monitor student performance, change parameters within the scenario and manage student information.

The Contractor shall provide an ergonomically designed Instructor's Console. The Instructor Console shall be networked with both student stations and shall control the stations and simulations through a user friendly, Windows based Graphical User Interface. The Instructor's Console shall be able to network and control up to four student stations for future expansion. The Instructor's Console shall have the capability for two instructor's to train simultaneously i.e. one on one training etc. Training sessions shall be conducted in either stand-alone or multi-participant simulations.

The Contractor shall include with the Instructor's Console shall a personal computer of the latest generation of sufficient processing power to:

a) Meet all optical/visual system performance requirements per Section 6.2 for combined use of the operator's module and instructor's console
b) Meet all Systems Requirements of Section 10
c) Meet all requirements of this Section 7
d) Meet all records storage requirements of Section 9.6
e) Meet all training function requirements of this specification

The Instructor shall be able to:

a) View the simulated bus being operated by the trainee while the instructor is driving another vehicle in the virtual world.
b) Observe on a separate viewing screen simultaneous views of each closed circuit camera image, or an individual camera feed. The Instructor shall be able to customize views. (section 6.5)
c) Utilize a third monitor to prepare and select a variety of scenarios and tools using windows based software, without interruption of the trainee program
d) Utilize a fourth monitor to view what the trainee is seeing through the front windshield.
e) Utilize a fifth monitor to facilitate two instructor operation, or shall be assigned as required.

All Instructors monitors shall meet the same performance requirements as the operator's video screens as detailed in Section 6.2

The Contractor shall also provide a multi-purpose steering wheel and pedals (to control a vehicle in the simulations), a joystick (to control a pedestrian in the simulations), wireless handheld controller (per Section 10.1), keyboard, mouse, laser printer, two high quality office chairs, and separate data storage hard drive.

8. SIMULATION SOFTWARE PERFORMANCE

8.1. Computer Generated Graphics

The BDSS software shall provide a seamless, panoramic, wrap-around visual simulation and shall incorporate all of the sight lines necessary to operate the new MBTA battery electric buses. The sight lines shall be presented at the proper distance and angle relative to the position of the student driver's eyes. The visual simulation shall present all of the peripheral and rearward scenery necessary to support the sight lines required to safely operate an actual bus.

The BDSS shall provide a continuous horizontal field-of-view of at least 315 degrees to support the presentation of visual simulation that shall be positioned forward and alongside of the student's driving station throughout the full range of operator seat positions (forward and aft).

The BDSS shall also present the student driver with a minimum of 45 degrees of vertical field-of-view from the top of the front dash to the top of the simulated front window.

The BDSS shall incorporate a rear-view presentation of visual information as it passes to the rear of the simulated vehicle. The rear-view presentation shall be correct and synchronous with the forward and side visual displays. The images in the rear-view presentation shall change position and orientation relative to the mirror surface in accordance with movement and changes to the angle of the student's head.

8.2. Virtual World

The BDSS shall present training opportunities with respect to basic skill development, battery electric bus energy optimization, situational awareness decision-making skills and judgment, vehicle maneuvering, and skills assessment for driver trainees, in the safe operation of BEBs in the MBTA's operating environment.

The BDSS shall simulate a variety of driving worlds that shall include at a minimum:

a) Street View World – Actual street view of MBTA bus routes including all bus stops, railroad crossings, intersections, etc.. The software program shall provide full student driver simulated BEB operation and feedback along Authority routes. The software program shall also include instructor options for Audio Simulation (8.3), Visual Stimulation (8.4), Interactive Vehicles and Pedestrians (8.6), and Motion/Action (8.7)
b) Urban World - A densely populated environment with a large variety of intersections with heavy vehicle and pedestrian traffic, numerous types of vehicles, parallel & double parked cars, and frequent stops.
c) Suburban World - This environment should include but not limited to residential and industrial settings with lower density of traffic, a variety of controlled and uncontrolled intersections, school zones, playgrounds, shopping malls etc.
d) Practice World - This environment is essentially a large, paved level area for practicing basic bus maneuvers. Various driving course layouts can be created through the use of virtual moveable cones or fixed barriers. The practice world shall also have the capability to simulate backing into a garage maintenance bay, Commercial Driving License training (CDL) test course, battery electric bus specific skid pad training (including regenerative braking), and bus maneuvers in confined locations including backing buses out of unsafe areas.

The simulated driving environment shall include varied driving surfaces such as pavement, grass, gravel, and dirt/sand with traction and sound variations on each for both dry, wet, snow, and icy conditions. Different weather conditions shall be selectable by the instructor, including clear, variable fog, rain, black ice, and snow. Different light conditions shall also be selectable by the instructor for time-of-day training experiences including: day, night, or dawn/dusk (including solar glare). In response to these variable conditions, the software shall make appropriate adjustments to the audio and visual simulation to reflect the performance of the bus being operated. The co-efficient of friction of the roadway should also be appropriately adjusted.

All visual training environments shall be integrated through the instructor station so that they may be readily used to support MBTA's training activities.

8.3. Audio Simulation

The following Audio simulation shall be provided to recreate the actual operating environment

a) Propulsion System – including the various operating and fault modes
b) Low Profile Tire – including the various conditions such as curb impact causing automatic blow out, skid, etc.
c) Horn – both from bus and from external vehicles

d) Braking system – under variable conditions (includes instructor ability to disable regenerative braking)
e) Passenger Door Operation
f) Passenger Stop Request
g) Reverse Warning
h) Turn Signal
i) Collision
j) Railroad Crossing – including activated gates, train, etc…
k) Emergency Vehicle Sirens
l) Weather – Wind and Precipitation
m) PA/VMS Announcements
n) All Technical Specification VE21-54 Instrumentation, Controls and Alarms in the actual BEB configuration (reference TS VE21-054 Table 7)
o) Parking Brake Unseat Alarm full operation in the actual BEB configuration (reference TS VE21-054 Section 40.6)

The audio simulation shall be programmed to replicate actual operation and feedback to the student and shall behave dynamically in reaction to the student's operation of the simulator controls.

8.4. Visual Simulation

The following visual simulation shall be provided to recreate the actual operating environment:

a) Pedestrians and Bicyclists
b) Other Vehicles - such as trucks, school buses, other buses, cars, emergency vehicles, motorcycles, etc..
c) Exterior bus mirror extents
d) Street and Traffic Signs – including fixed signage and dynamic signage that can be modified to convey a specific message that is subject to change
e) Traffic Signals
f) Railroad Crossing – including activated gates, train, etc…
g) Street Curbs
h) Street Dividers or Medians
i) Street Markings
j) Road Obstacles, Potholes, and Hazards
k) Fire Hydrants
l) Bus Shelters
m) Buildings
n) Trees and Foliage
o) Telephone Poles and Lamp Posts
p) Bus facility storage area parking markings and facility pantograph down charging equipment
q) Propulsion System – including the various operating and fault modes
r) Energy Storage System state of charge indications
s) All Technical Specification VE21-54 Instrumentation, Controls and Alarms in the actual BEB configuration (reference TS VE21-054 Table 7)
t) Parking Brake Unseat Alarm full operation in the actual BEB configuration (reference TS VE21-054 Section 40.6)

The visual simulation shall be programmed to replicate actual operation and feedback to the student and shall behave dynamically in reaction to the student's operation of the simulator controls.

8.5. Interactive Vehicles & Pedestrians

The BDSS simulation program shall contain Interactive Vehicles and Pedestrians (IVPs) which can be programmed and introduced by the instructor to create a real world operating environment and serve as the dynamic traffic elements. IVPs generally adhere to specific traffic rules that govern their behavior as they travel through the virtual environments.

The software shall allow an IVP to forecast whether another vehicle (such as the student's or instructor's vehicle) shall obstruct their path of travel in any way. If given enough space and time to react, the IVP shall attempt to avoid having a collision with another vehicle by stopping as swiftly as possible. If conditions do not permit sufficient time for an IVP to make an evasive response, a collision shall occur. The instructor shall be able to pause/rewind/replay/repeat/jump back that segment of the simulation to allow the student another attempt to avoid an accident.

The software shall allow up to sixty IVPs to operate in close proximity to the student-operated vehicle. The density of IVPs present during the simulation exercise can be selected by the instructor to support the training objective and shall have graduated levels of interaction including passive, normal and aggressive.

8.6. Motion/Action

The BDSS shall simulate the full bus motion/action/reaction behavior of the BEB, as that bus would interface with all actual operating conditions. The BDSS shall reflect the dynamics, bus subsystems, operator's compartment equipment, performance, functions, controls, and displays of the Authority's new BEB. The dynamic simulation shall reflect the following factors:

a) Gradient and curvature of the roadway
b) Aerodynamic resistance
c) Vehicle weight (including empty, seated, and standing passenger load)
d) BEB performance characteristics and energy storage system status
e) Effects of low battery state of charge load shed
f) Instructor programmable weather conditions and effects on energy (battery) consumption
g) Center of gravity and acceleration/deceleration
h) Air brakes, ABS, traction control, dynamic/regenerative braking and spring parking brake characteristics, application, and status
i) Friction brake adhesion coefficient
j) Tire adhesion
k) Drive mode selection.
l) Turning radius
m) Road conditions and response to curbs, potholes, cobble stone, speed bumps and collision
n) Energy Storage System (ESS) consumption based upon driving style, climate, roadway grade, etc.

The student shall experience the resultant physical effect of the above factors in the response (motion/vibrations) in the seat, the steering wheel and foot pedal controls.

8.7. MBTA Specific Software

The Contractor shall provide BDSS software to specifically simulate the MBTA's as delivered battery electric bus as configured per TS VE21-054. The software shall be capable of the BEB simulation in street view and all virtual worlds. In addition, the Authority requires custom software to replicate some of the Authority's unique operating environments

8.8. Bus Operating Environment / Route Profiles

The Contractor shall provide interactive street view software each bus route emanating from the North Cambridge, Quincy, and Arborway facilities. The software must provide route specific details such as bus stops, traffic lights, railroad crossings, traffic circles (rotaries), etc.

The MBTA may change existing bus routes, whether as part of the ongoing MBTA Network Redesign, or seasonal such as snow routes, or to meet evolving community needs. The Contractor shall revise all BDSS software systems MBTA bus routes and route details for five years from the date of BDSS acceptance, at no cost to the Authority.

Existing route API and GTFS files are available at https://www.mbta.com/developers

MBTA Bus Network Redesign information is available at https://www.mbta.com/projects/bus-network-redesign

8.9. Negotiating Boston Rotaries

There are several rotaries unique to the Boston area that are difficult for operators to negotiate with a bus. Unique simulations for the Sweetser rotary and the Preble Street rotary shall also be created. The density and aggressiveness of the AVs in the rotaries shall be selectable by the instructor.

8.10. MBTA "Training Day 8" Route Simulation

The contractor shall simulate the route traveled by students on the eighth day of the Authority's current training program. The route incorporates a diverse mixture of the most challenging roadways for the Authority's operator trainees (10 miles long maximum). The simulation shall be constructed in such a way as to allow easy segmentation and modification into additional training modules. The Authority shall provide the latest revision of the Training Day 8 Route simulation during the initial design review meeting.

8.11. Energy Storage System Consumption

The BDSS shall accurately portray the RFP 1F-22 base order battery electric bus in the 'as accepted' configuration to include the energy storage system (ESS) size and all operating equipment and bus weight. The BDSS software shall use the actual bus configuration to provide all simulation calculations for ESS consumption and simulated bus operating characteristics in the MBTA operating environment.

The Contractor shall provide all core data points and ESS consumption calculations during the design review process. All core data points, to include ESS size, vehicle weight, etc. shall be Authority

editable.

9. OPERATOR TRAINING/INSTRUCTOR CONTROLS

9.1. Training Scenarios

The instructor shall be able to set-up and conduct driving training scenarios from the supervisor station. During the simulation the instructor shall have control of the scenario and shall be able to alter conditions such as weather, traffic density, traffic aggressiveness, road conditions, pedestrian actions, time of day, as well as initiate specific events.

The Contractor shall provide several training scenarios for review by the MBTA during the design approval process. The MBTA shall have the ability to customize and refine these scenarios. The Contractor shall also provide training to MBTA instructors on how to conduct the training simulation. There shall be a description of each training scenario as well as the suggested teaching/learning points.

9.2. Basic Bus Operator Training Programs

The following Basic Bus operator training program shall include:

a) Bus Operator – Initial Qualification Screening
b) Bus Operator – New Operator Training
c) Bus Operator – Re-certification
d) Bus Operator – Defensive Driving
e) Bus Operator – Route Specific BEB Operation Training
f) Bus Operator – Battery Electric Bus Energy Consumption Optimization
g) Bus Operator – Battery Electric Bus Familiarization and Operation
h) Bus Garage Operator – Initial Qualification Screening
i) Bus Garage Operator – New Operator Training
j) Bus Garage Operator – Re-certification
k) Bus Garage Operator – Backing-up as required within a maintenance facility

9.3. Additional Training Programs

The following additional training programs shall also be provided:

a) Lane discipline / straight line bus handling
b) Negotiating curves
c) Maneuvering around fixed objects
d) Left and right hand turns
e) Battery Electric Bus Pantograph Down Charging to include bus positioning and simulated connection and disconnect from facility chargers
f) Commercial Driver's License (CDL) test drive course
g) Spot Pond simulation – this shall simulate the MBTA current operator initiation training, to include a series of long curved roads, incorporating two lane and four lane traffic, lane merges, and grades.

h) Accident simulation
i) Bus faults
j) Regenerative braking and BEB braking techniques
k) Reaction time and stopping distance test
l) Harvard Square busway
m) Negotiating Boston rotaries
n) The MBTA's actual "Training Day 8" route

All Training Programs and scenarios shall include the ability for the instructor to initiate hazards and defects, and allow for appropriate student/driver/instructor response and remedial action.

9.4. Custom Training Exercises

The Contractor shall provide training to Authority personnel on how to edit and create new scenarios based on the existing virtual world.

The Contractor shall provide training to Authority personnel on how to input and create new bus routes into the simulation system.

The instructor shall be able to re-create actual accident and/or collision scenarios using standard templates. Possible collision scenarios shall include bus with other vehicles, stationary objects, buildings, and pedestrians.

Software shall be provided with the Instructor's computer workstation. The software shall enable the instructors to create new, or edited training scenarios, using standard templates.

9.5. Training Features

The BDSS software, as controlled by the Instructor's console, shall permit the Instructor to accomplish the following:

9.5.1. Freeze/Re-Start

In order to emphasis student responses in the simulation and to point out learning moments, the instructor shall be able to pause the simulation at any time. The instructor shall be able to restart the training at the same location, replay a section, or skip ahead to another location in the simulation.

9.5.2. Replay/Re-Drive

In order to emphasis student responses in the simulation and to point out learning moments, the entire simulation shall be recorded and saveable. This shall allow the instructor to re-play specific moments of the simulation, highlight the student's response to situations and/or point-out alternative responses.

9.5.3. Jump Back

The simulator's jump back feature shall allow Authority instructors to simultaneously review vehicle actions and closed circuit Instructor's views (Section 6.5), and further permit the instructor to "jump back" to a specific moment for the student to retry a scenario. During jump back, all simulator interactions must be viewable, recordable, controllable, and repeatable.

9.5.4. Control of Vehicle

The instructor shall be able to control a secondary vehicle in the simulation in real time. Using the steering wheel and pedal controls provided with the Instructor's Console, the instructor shall be able to operate the secondary vehicle in the student's simulation. The instructor vehicle shall respond to the instructor console steering and accelerator/brake controls. The interactive traffic and pedestrians (IVP Section 8.5) shall react to the instructor vehicle using the same rules and methods as the student's simulated bus.

9.5.5. Control of Virtual Persons

The instructor shall be able to control the movements and actions of pedestrians, persons using mobility devices, and persons using service animals, in the simulation in real time. The instructor shall control movements using handheld controllers with thumbsticks. The instructor shall be able to move a pedestrian through the following motions: crouching, walking, running, and standing. The instructor shall be able to move all persons and service animals in and out of blind-spots, between cars, from behind buildings, and running for the bus. The interactive vehicles, pedestrians, persons with mobility devices shall react to the instructor controlled pedestrian.

9.5.6. Instructor Initiated Hazards, Defects, and Props/Scenarios

The instructor shall monitor and control the simulation and shall be able to initiate the following hazardous events:

a) Change an approaching traffic signal
b) Open driver's door of parked car
c) Parked car pulling into traffic
d) Insert / remove parked vehicles at corners, bus stops etc
e) Change bus stop locations
f) Cause leading vehicle to stop suddenly
g) Cause leading vehicle to suddenly change lanes (with and without turn signals)
h) Cause on-coming vehicle to swerve over center line into bus' path
i) Alter weather conditions

The instructor shall be able to initiate vehicle defects/failures such as:

a) Low air system pressure (primary and secondary separately or together)
b) Flat tire, tire blow-out
c) Exit door failure (door interlock activation)
d) Stop system light
e) Alternator failure
f) Low state of charge
g) Low coolant
h) Thermal event detection
i) propulsion system failure
j) Fuel leak
k) Loose lug nut/loose wheel
l) Dragging brake
m) Loss of regenerative braking

n) Any BEB warning light or audible indicator as noted in Sections 8.3 and 8.4

The instructor shall monitor and control the simulation and shall be able to initiate the following events:

a) Persons using wheeled mobility devices, walkers, and canes
b) Persons relying on service animals
c) Unruly passengers on the bus
d) Virtual passengers entering the bus
e) Traffic and related incidents

The instructor shall monitor and control the simulation and shall be able to create the following props:

a) Traffic signs (all types)
b) Fences (all types)
c) Tress
d) Bus stops
e) General signage (example: street, route, bus stop, warning, etc.)
f) Crowds

All defect and failure conditions shall be accompanied by the appropriate alarms, gauges, and indicators. The simulation shall respond with the appropriate sounds, visualizations, and changes in vehicle performance.

9.6. Student Reports

The BDSS shall generate a record of the student performance during the simulation. The BDSS shall monitor driving performance such as speed limit adherence (both high and low), following distance, braking performance, energy consumption, reaction and adherence to vehicle warning indicators, and lane positioning.

The student report layout/format shall be approved by the Authority. It shall include: student name, employee number, instructor name, date, and the various test results. There shall also be a comment block where the instructor can enter additional comments and observations regarding the student's performance.

The instructor's workstation computer shall store the student operator reports in a searchable database. The database shall be Microsoft Windows based, commercial program capable of storing a minimum of 2000 separate student records per year for a minimum of three years. The records shall be readable by standard Windows PC based programs. The instructor's computer shall have extra USB ports.

9.7. Simulator Maintenance/Administration

The Instructor's computer workstation shall have a dedicated login for a BDSS Administrator to perform simulator maintenance and diagnostic tests to verify BDSS operation, edit systems programs, and to perform software upgrades.

10. SYSTEM REQUIREMENTS

10.1. Computer and Software

The Contractor shall provide the instructor's console computer:

a. sufficient to store student reports per the requirements of Section 9.6
b. sufficient to efficiently operate all simulations without lag or lag effects on simulated vehicle and scenario speeds
c. spare USB and HDMI ports
d. Microsoft Windows based
e. Configured with Microsoft 365 Business Standard, Adobe Creative Cloud for Business, and anti-virus software
f. Wireless connectivity
g. Programmable
h. Meet all requirements of Section 7

The Contractor shall also provide:

a. Wireless handheld controller with thumbsticks for instructor use. The handheld controller shall allow the instructor mobility during instruction and have the full function of the complete desktop control system
b. APC with surge protection for simultaneous use and protection of the full BDSS system
c. All cables, and wiring needed to connect all components in the system
d. Any power supply cord
e. External hard drive for additional data storage (no less than 5 TB)

The Contractor shall be responsible for all software, app, and subscription costs, to include updates and changes to all software and apps (example: Office 365 change to Microsoft 365) for five years beginning with the date the BDSS is accepted by the Authority.

The MBTA may change existing bus routes, whether as part of the ongoing MBTA Network Redesign, or seasonal such as snow routes, or to meet evolving community needs. Upon request by the Authority, the Contractor shall revise all BDSS software systems MBTA bus routes and route details for five years from the date of BDSS acceptance at no cost to the Authority. The Contractor shall provide any revised software and route updates in no less than thirty calendars days following an Authority request.

The Contractor shall provide all software, programs, and training necessary for the MBTA to modify or add any scenario, action, or bus route in the BDSS system. The Contractor shall provide annual systems and programming training to three Authority representatives for five consecutive years from NTP at no cost to the Authority.

The Contractor shall adhere to all RFP 1F-22 Section 10.21 and Technical Specification VE21-54 Section 79 Software Configuration Control Requirements.

The Contractor shall adhere to all requirements of Technical Specification VE21-54 Section 80 Software Escrow.

10.2. Additional Requirements

The Contractor shall provide complete system support for all simulation hardware, training curriculum, supporting software applications, instructor training, as well as warranty/service support.

11. QUALITY ASSURANCE REQUIREMENTS

11.1. Quality Assurance Organization

The Contractor shall have planned and established a documented quality assurance program in compliance with ANSI/ISO/ASQ Q9001-2008 or latest revision.

11.2. Work Instructions

The quality assurance team shall verify inspection operation instructions to ascertain that the manufactured BDSS meets all prescribed requirements.

11.3. Plan and Test Procedures

The quality assurance team shall prepare a test plan for all testing of components, assemblies and subassemblies of the BDSS. The test plan shall be provided during the design review process.

11.4. Corrective Action

The quality assurance team shall detect and promptly assure correction of any conditions that may result in the production of a defective BDSS. These conditions may occur in designs, purchases, manufacture, tests, or operations that culminate in defective supplies, services, facilities, technical data, or standards.

11.5. Configuration Control

The quality assurance team shall verify that the bus simulator is manufactured in accordance with this specification requirements and engineering design.

11.6. Manufacturing Control

The Contractor shall ensure that all basic production operations, as well as all other processing and fabricating, are performed under controlled conditions. Establishment of these controlled conditions shall be based on the documented work instructions, adequate production equipment, and special working environments if necessary.

11.7. Completed Items

A procedure for the final inspection and test of the completed driving simulator shall be provided by the quality assurance team. It shall measure the overall quality of the BDSS.

12. SOFTWARE QUALITY ASSURANCE / VERIFICATION

The Contractor shall ensure that any changes to the basic industry proven software package is authorized and recorded by the Software Development Team, which consists of software engineers and Software Quality Assurance (SQA) personnel. If the Authority requires any customized virtual world needs to be developed, the contractor shall provide their Software Management Plan. The plan shall consist of the software development and quality assurance plans to understand the process used to develop and control the software changes. All software changes must be documented and provided to the Authority per RFP 1F-22 Section 10.21 and Technical Specification VE21-54 Section 79 Software Configuration Control Requirements.

13. ACCEPTANCE TESTS

13.1. Responsibility

The proposed test plan / procedures shall be prepared by the Contractor and submitted to the Authority for approval. These test plan shall include a complete series of pre-delivery inspections and testing by the Contractor, and inspections and testing by the Contractor and Authority upon delivery and installation at the MBTA.

13.2. Pre-Delivery Tests

The Contractor shall perform fully documented tests on the completed BDSS following manufacture to determine its compliance to Authority requirements and confirm proper functionality. The BDSS must pass all required tests prior to delivery to the MBTA. These pre-delivery tests shall include visual and measured inspections, as well as testing the total functionality of the BDSS. Total functionality shall include verification of all scenarios, systems and controls functions, and route sampling. The tests shall be conducted and documented in accordance with the contractor's written test plans / procedures. The Authority may elect to have representatives participate in Pre-Delivery tests.

13.3. Post-Delivery Tests

The MBTA and the contractor shall jointly conduct acceptance tests on the delivered BDSS. These tests shall be completed within 15 (fifteen) days after BDSS delivery and shall be conducted in accordance with the approved written test plans and procedures. The purpose of these tests is to identify any defects that have become apparent between the time of BDSS release and delivery to the MBTA and to perform pilot training to confirm proper functionality of all simulation scenarios and system features. The post-delivery tests shall include visual inspection and BDSS functional operations.

Any visual delivery damage shall be identified and recorded during the visual inspection of each BDSS components.

Driving simulators that fail to pass the post-delivery tests are subject to non-acceptance. The MBTA shall record details of all Defects and shall notify the BDSS manufacturer of non-acceptance of each BDSS within five days after completion of the tests. The Contractor shall correct any defect or systems issues within five workdays of notification. All concerns, system issues, and defects, must be corrected prior to Authority acceptance of the BDSS.

14. WARRANTY REQUIREMENTS:

14.1. Contractor Warranty

The Contractor shall warranty and guarantee to the MBTA a complete BDSS to be free from defects for five (5) years. The Contractor shall pass on to the Authority any extended warranty offered by a sub supplier i.e. computers, screens, controllers, etc, that is superior to that required herein. During the respective period of the warranty, all BDSS parts or material damaged as a result of a failure, malfunction, defect in design, material, or workmanship in other parts or material, shall be repaired or replaced at the expense of the Contractor.

14.2. Complete Bus Driving Simulator System

The complete BDSS (hardware and software) are warranted to be free from Defects and Related Defects for five (5) years, including full version software upgrades and unlimited on site repairs and preventive maintenance, beginning on the date of acceptance of the BDSS. The warranty shall cover all parts, labor, and associated expenses required to preserve full operational capability of the delivered equipment. The warranty is based on regular operation of the driving simulator under the training conditions prevailing in the MBTA training environment.

14.3. On-Site Technical Support

The contractor shall identify a technical support representative available by phone during normal business hours throughout the warranty period. The technical support representative shall help diagnose and troubleshoot any and all problems.

On-site technical support & services shall be provided by a fully trained technician within forty-eight (48) hours of a reported failure for the duration of the five year warranty period. The technician shall arrive on site equipped with the required tools and parts to repair the BDSS.

14.4. Extension of Warranty

If, during the warranty period, repairs or modifications to any portion of the BDSS, made necessary by defective design, failed materials or workmanship, are not completed due to lack of material or inability to provide the proper repair for 30 calendar days, the applicable warranty period shall be extended by the number of days equal to the full delay period